Stellar populations in bulges of spiral galaxies

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Abstract. We discuss the integrated properties of the stellar population in bulges along the Hubble sequence and new HST data for individual stars in the bulge of M31.

1 Bulges along the Hubble sequence

Bulge stellar populations are still poorly investigated. It remains unclear whether bulges are formed in the very early stages of galaxy formation in synchronicity with the halo, or on the contrary on longer time scales and from disk material. The effective role of bars in bulge growth and star formation is also to be clarified. The bulge-to-disk light ratio varies along the Hubble sequence, and it is important to understand whether this trend translates into a mass scale only or into differences of star formation history as well. For a long time, the bulge of our Galaxy has been considered as the prototype of bulges in general. However, no blame on this simplification, since the study of bulges, although imperative, has to cope with the difficult problem of the contamination of bulge by disk light.

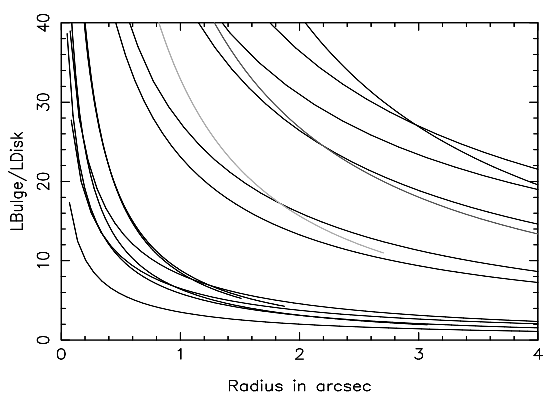

Fig. 1. The radial variation of the bulge-to-disk luminosity ratio in 28 spiral galaxies.

Taking advantage of Kent (1985) work on decomposition between disk and bulge lights, we show in Fig. 1, for a few face-on spiral galaxies, the radial variation of their bulge-to-disk light ratio, L_{Bulge}/L_{Disk}. It is conspicuous that the integration of light in a constant aperture for all these galaxies would gather

different amount of disk light. This would severely affect any search for trends of bulge properties along the Hubble sequence. Also, this disk light contamination can be present even in the central regions of galaxies. Therefore, observations of bulges require the acceptance of some disk light contamination, yet this contamination must be kept as small as possible and in equal proportion for all galaxies; this can be done by having a different aperture for each galaxy.

The integrated-light spectra of 28 spiral galaxies were obtained in 1993, using an automatic drift scanning procedure available at the Steward Observatory 2.3-m telescope equipped with a Boller & Chivens CCD spectrograph. For each galaxy, structural parameters, such as effective radius r_e, scale height h, surface brightness values μ_e at r_e and μ_0 at the center were available (Kent 1985). Consequently, we were able to calculate the radius corresponding to a fixed value of the bulge-to-disk luminosity ratio, a ratio equal to 6 for all sample galaxies.

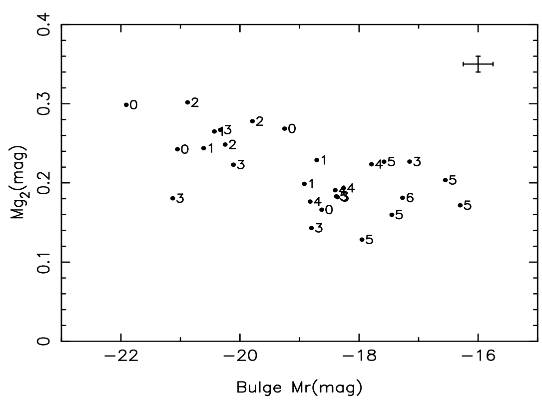

Fig. 2. The relation between the bulge total r-Gunn luminosity and Mg_2 index. Numbers represent the galaxies Hubble types (T parameter). Typical maximum errors are shown.

Fig. 2 presents the variation of the bulge Mg_2 index with its absolute magnitude in r-Gunn photometric band. The Hubble type of each galaxy is indicated by its corresponding number. There is clearly delineated a metallicity-luminosity relation for bulges along the Hubble sequence: the bulge of our Galaxy can no longer be considered as a template for all bulges. If bulges tend to be fainter in late-type spirals than in early-type ones, this is however the only segregation seen in Fig. 2. Besides this tendency, all Hubble types are mixed; the bulge luminosity is certainly the dominant factor in the correlation.

Fig. 3 displays the relation existing between the bulge Mg_2 index and the galaxy central velocity dispersion, when this information is available. This is the case for about half the galaxies in our sample. Our own Galaxy is indicated by an asterisk and the mean relation obtained for elliptical galaxies (Gorgas & Gonzàlez, private communication) is superimposed with its 1-σ dispersion. This figure underlines how bulges and elliptical galaxies are closely related systems

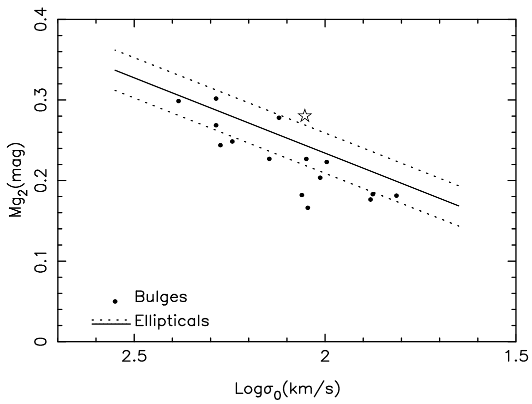

Fig. 3. The variation of the bulge Mg_2 index with the central velocity dispersion σ_0. Plain and doted lines represent the mean relation and 1-σ dispersion known for ellipticals (Gorgas & Gonzàlez, private communication). The open asterisk indicates the bulge of our Galaxy.

and suggest common processes of formation.

2 The bulge of M31

The high inclination between the disk of M31 and its line-of-sight allows the study of the stellar populations of its bulge. The view we have of it is global and essentially free of pollution by disk stars, unlike the case for the bulge of our Galaxy.

We obtained, with the WFPC2 camera on the Hubble Space Telescope, Cycle 5 and 6 high spatial resolution images, in filters F555W and F814W, of a few fields centered on super-metal rich star clusters in the bulge of M31, clusters for which we have ground-based spectrophotometric data (Jablonka et al. 1992). Two clusters, G170 and G177, are located SW along the major axis of M31, respectively at 6.1 and 3.2 arcmin of the galaxy nucleus; another cluster, G198, is located NE along the major axis at 3.7 arcmin (Huchra et al. 1991). Adopting 1 arcmin = 250 pc from Rich & Mighell (1995), these separations correspond to projected distances of about 1.55, 0.80, and 0.92 kpc, respectively. In addition to the cluster stellar populations, these HST data give us the opportunity to study the stellar populations in the surrounding bulge fields. We present hereafter some of the results on the latter point, which are part of an extensive work to be published elsewhere (Jablonka et al. 1997).

Fig. 4 displays the cluster G177 and its surrounding bulge stellar field, as observed in the PC frame. The field is 36 arcsec by 36 arcsec in size. It is a composite image from the F814W and F555W frames. The total exposure time is 6500s in the filter F555W and 6000s in the filter F814W. This figure illustrates the compactness of the cluster G177 and the richness of its surrounding field.